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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Air Compressor
Cylinder
Lubrication

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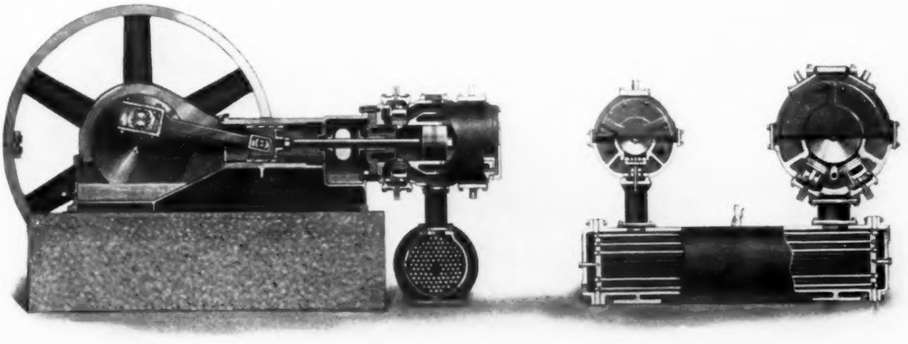


Courtesy of Worthington Pump & Machinery Corp.

Fig. 1.—Sectional elevation of a duplex two-stage compressor.

Air Compressor Cylinder Lubrication

IN THE operation of certain types of mechanical equipment, faulty lubrication or the use of lubricants which are unsuited to the operating requirements of the machinery may often lead only to troublesome difficulties and inefficient operation. There are, on the other hand, cases where even expensive shutdowns may result. Relatively few machines however, will involve, as does the Air Compressor, the combined possibility of not only a cessation of operation, but also, the possibility of explosion in event of:

1. Improper selection of the air cylinder lubricant.
2. Excessive feeding of the lubricant.
3. Oil pockets occurring in the system, due to improper design.
4. The absence of an after cooler (by which oil accumulations and dirt can be removed).
5. Discharge piping being too small or congested to be able to handle the requisite volume of air without the necessity for a decided increase in its velocity, and consequently its temperature.
6. The occurrence of air leaks on account of inefficient delivery valves.
7. The continued compression of air which is not free from dirt. The air intake should therefore, be so located as to secure clean, cold air, or a suitable air filter should be used.

Air compressor lubrication is, consequently, looked upon as an important problem by both the lubricating specialist and the power plant engineer.

In the compression of air, work must be done; as a consequence, heat is developed, temperatures rising as the pressures are increased. The evolution of heat by the expenditure of work is

a natural physical phenomenon. Machine operation in general brings about this occurrence to a more or less extent, depending upon the friction involved. Normally, however, such heat will have opportunity to dissipate itself in some manner or other, either by radiation or conduction. In the air compressor, the heat developed is not a result of friction; it is, rather, the consequence of an increased rate of impact between the molecules of air composing the charge which is being compressed in the cylinder.

Temperatures Involved

The rise in temperature of a volume of air under compression follows certain laws. Data has been compiled which shows the theoretical temperatures that air will attain when subjected to certain increased pressures of compression. The following table gives an interesting insight as to the theoretical final temperatures involved at various pressures when compression is completed, the air being taken into the cylinders at 60 degrees Fahrenheit.

TABLE No. 1

Cylinder Temperatures at End of Piston Stroke

Air Compressed to	*Final Temperature Single Stage*	*Final Temperature Two Stage*
10 lbs. gauge	145 degrees F.	
20 lbs. gauge	207 degrees F.	
30 lbs. gauge	255 degrees F.	
40 lbs. gauge	302 degrees F.	
50 lbs. gauge	339 degrees F.	188 degrees F.
60 lbs. gauge	375 degrees F.	203 degrees F.
70 lbs. gauge	405 degrees F.	214 degrees F.
80 lbs. gauge	432 degrees F.	224 degrees F.
90 lbs. gauge	459 degrees F.	234 degrees F.
100 lbs. gauge	485 degrees F.	243 degrees F.
110 lbs. gauge	507 degrees F.	250 degrees F.
120 lbs. gauge	529 degrees F.	257 degrees F.
130 lbs. gauge	550 degrees F.	265 degrees F.
140 lbs. gauge	570 degrees F.	272 degrees F.
150 lbs. gauge	589 degrees F.	279 degrees F.
200 lbs. gauge	672 degrees F.	309 degrees F.
250 lbs. gauge	749 degrees F.	331 degrees F.

Courtesy of The Compressed Air Society

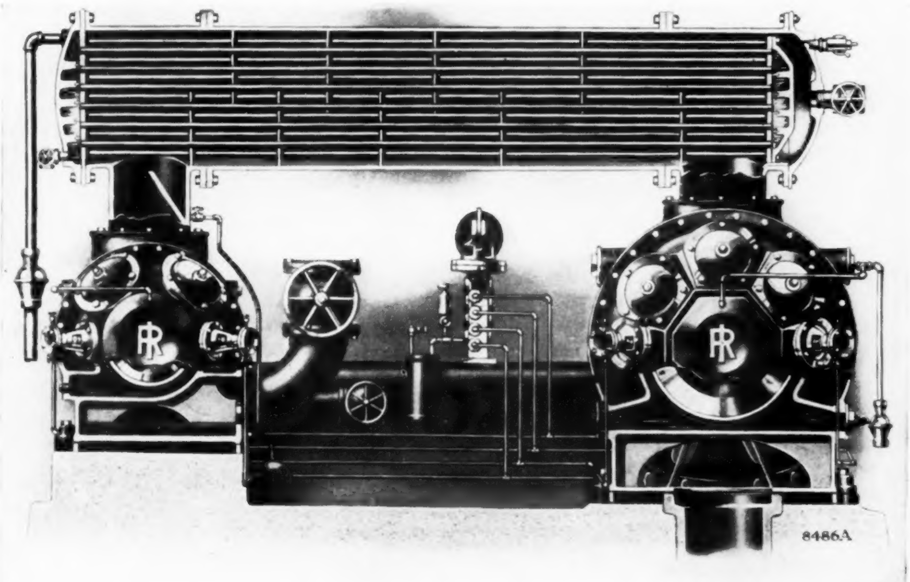
In actual practice, however, variations from these maximum temperatures will always be found. In fact, operating temperatures especially with single stage compressors will never be as high as shown, for the reason that the compressor cylinders and cylinder heads are provided with jackets through which cold water is circulated to absorb as much of the heat of compression as possible. If the water jackets are of insufficient capacity or if too warm or too small an amount of water is circulated through them, the cylinder temperature will naturally be higher. A large percentage of the trouble experienced with air compressors occurs on single stage machines. Examinations have shown that in many instances this is due to the fact that they are overloaded or forced beyond their capacity, and excessive heat is generated as a result.

Where the air is compressed through more than one cylinder, the temperature of the compressed air is still further reduced by passing it through intercoolers on its way from one cylinder to another. These intercoolers connect the discharge of the first cylinder with the suction or inlet of the second cylinder. In case the air is to be still further compressed successively through additional cylinders, intercoolers are placed between each pair of cylinders. These intercoolers contain a number of small tubes around which the air passes and through which the cooling water circulates. In this way the air, even when compressed to 1000 pounds or more per square inch will, after passing from the last cylinder and through the aftercooler, be comparatively cool. In fact, the final discharge from a multiple cylinder compressor is often cooler than from a single cylinder machine compressing to only 80 or 100 pounds pressure, especially where the single stage machine is driven at high speed.

Normal operation is therefore non-productive of dangerous temperature conditions. On the other hand, normal operation is never an assured factor. The slightest air leak or deficiency developed in the working of the delivery valves will lead to the building up of excessive temperatures due to hot air being drawn back into the cylinder and re-compressed. This will often occur repeatedly, with the ultimate possibility of failure or explosion resulting.

In this connection we must realize that all lubricating oils will be subject to more or less fractional distillation or separation under high temperatures. As this breaking down continues, the lighter portions evaporate and are carried off with the discharged air, the heavier fractions meanwhile remaining in the cylinder or collecting in the heads or on the valves. These oily deposits gradually thicken, carbonize, and collect dust drawn in with the air,

(unless the latter is clean, or has been filtered) finally developing to such an extent that they may interfere with the operation of the valves. It is really the dust from the air in company



Courtesy of Ingersoll-Rand Company

Fig. 2.—Transverse section through cylinders and intercooler of a two-stage compressor showing details of intercooler baffles, etc.

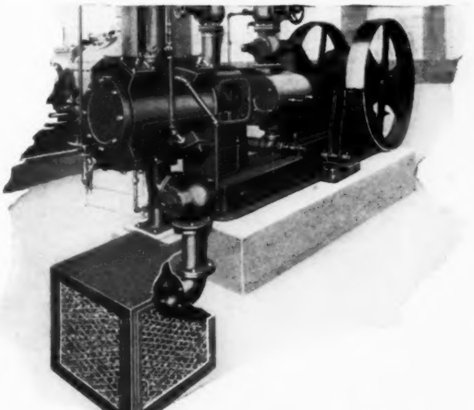
with gummy oil deposits (known as carbonaceous matter) from improperly refined oils, or the excessive use of oil, which brings about faulty valve action. If the original oil is a highly refined, filtered, low flash test product, and is not used to excess, the greater proportion of it will vaporize completely and pass over to the aftercooler with the discharged air.

Types of Compressors

In order to more fully appreciate the subsequent remarks regarding lubrication, the basic constructional features of the several types of air compressors on the market today must be understood. In general, we will be concerned with:

1. Single stage reciprocating compressors.
2. Multi-stage or compound reciprocating compressors.
3. Rotary compressors.
4. Blowers of the centrifugal or rotary type.
5. Blowing engines.

Single stage compressors or compressors subjecting air to but one compression, are built both single and double acting and may be either horizontal or vertical. They are used for the compression of air up to approximately 80 pounds. Vertical single-stage compressors are generally of the one-cylinder, single acting variety. The piston in these machines is usually of the trunk type, the upper section carrying one or more rings which seal the cylinder

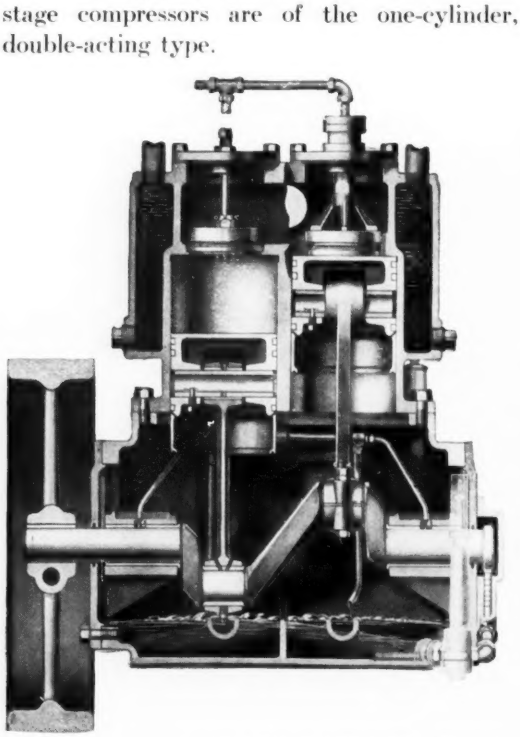


Courtesy of Midwest Air Filters, Inc.

Fig. 3.—An air filter installed on the air intake of a compressor to insure the usage of dust-free air, and eliminate subsequent possibility of dangerous deposits occurring in the intercooler and air lines. Clean cool air is a most important factor in air compressor operation.

and prevent excess oil from being drawn in or splashed since they are generally splash lubricated. The lower portion of the piston usually

carries one ring only. Vertical single-stage compressors are built in various sizes from one cubic foot capacity upward. Horizontal single-stage compressors are of the one-cylinder, double-acting type.



Courtesy of Chicago Pneumatic Tool Company

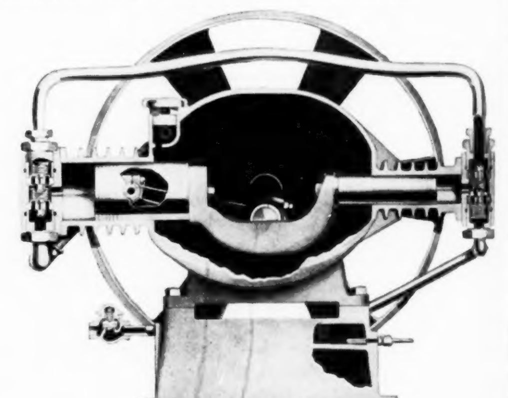
Fig. 4.—Section of a vertical water-cooled air compressor. Both splash and force-feed lubrication are employed to serve the bearings and cylinders. A small plunger pump draws oil from the reservoir and feeds it to the main bearings and splash pans.

Multi-stage reciprocating compressors wherein air is subjected to two or more compressions, are used when high pressures in excess of 80 pounds are desired. In compressors of this type, the air receives an initial compression in one cylinder. Passing through an intercooler which serves to reduce the temperature, it is then compressed in a second cylinder and so on in succession until the desired compression pressure is attained.

Because of the more effective cooling and because clearance losses are reduced, multi-stage compressors are more efficient. Theoretically, therefore, the more stages the higher the efficiency, but size and cost of machinery, as well as frictional losses limit the number of stages to five at the most. In such machines, pressures of from 1000 to 5000 pounds are attainable.

Rotary compressors differ widely in design but as a rule use either sliding vanes rotating in an eccentric housing or rotating gears or cams so arranged as to alternately increase and decrease the enclosed air space. This type has not attained such general application as the piston type, both because of the complexity of the moving parts and its inability, as a general rule, to produce large volumes and high pressures as easily as the piston compressor. In certain specific cases, however, the rotary compressor is quite efficient and the opportunity for future development is great; in addition, its lubrication requirements are less exacting.

Blowers may be of either the centrifugal or rotary type, and are built to supply large quantities of air at low pressures. The centrifugal fan blower consists of a more or less scientifically designed "paddle-wheel," revolving in an eccentric casing. These operate at pressures below one pound and are much used in heating and ventilating. Blowers of the bucket type develop along with the centrifugal action, a certain pressure due to the shape of the bucket or blade. They may often impart a velocity to the air in excess of the peripheral speed of the rotor. In any centrifugal machine, no lubrication of the air side is involved.



Courtesy of The United States Air Compressor Co.

Fig. 5.—A small two-stage self-contained air compressor adaptable to garage service. Splash lubrication is carried out in this machine by use of splash pins, and baffle plates for diverting oil to proper points.

Blowing engines are very large, slow moving reciprocating compressors, which are employed principally in iron and steel plants for supplying large quantities of comparatively low pressure air to the blast furnaces. Blowing engines may be either horizontal or vertical in construction; as a rule, they present no unusual lubricating difficulties.

Compressor Oil Requirements

The difficulties that will confront the operator in providing for proper lubrication of reciprocating air compressors are largely due to the possible extreme temperatures to which the oil may become exposed in the compressor, and to the fact that the oil (if not properly refined) on coming in contact with heated air, will tend to deteriorate, carbonize and become a source of subsequent trouble.

As in the case of steam cylinder lubrication, the conditions of the internal surfaces, the piston speed, and the weight and fit of the piston must be taken into consideration in selecting the proper air compressor oil. Low speeds and heavy or loose fitting pistons require a higher viscosity oil than high speeds and light or tight fitting pistons. Other important factors which govern the lubrication of air compressors are, the degree to which the air is to be compressed, the location of the air inlet, the method of applying the lubricants, the kind of valves used, and the size and kind of water jackets, etc.

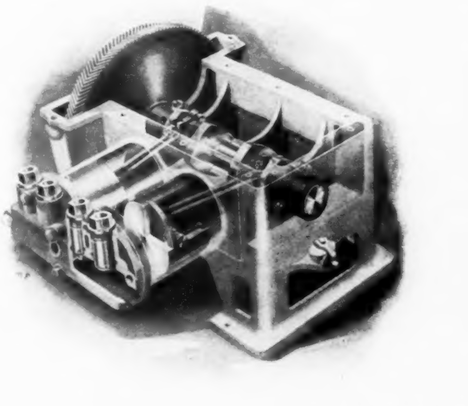
In the horizontal air compressor, as in the horizontal steam engine, the entire weight of the compressor piston must often be sustained by the lower portion of the compressor cylinder. With this type of compressor it is, therefore, necessary to use a lubricant which will have sufficient body at the temperature of compression to prevent metal to metal contact, and reduce wear to a minimum. Vertical compressors do not require as much or as heavy a lubricant as horizontal compressors.

To meet operating conditions discussed above, an air compressor oil must possess certain very definite properties if it is to function effectively and without undue possibility of developing into a hazard by virtue of subsequent decomposition. Broadly speaking, the essential characteristics which will indicate the ability of the oil to meet requirements are:

(a) The viscosity.
(b) The flash and fire points.
(c) The tendency to form carbon deposits.

Relation of Viscosity

In air compressor lubrication, the viscosity of the oil is a far more important characteristic than many will imagine. Upon the viscosity will depend the piston seal that will be obtained, and consequently the efficiency of compression. If the oil is too light in body (low in viscosity) at the operating temperatures in the cylinder, it will work past the piston rings on the compression stroke. This, in connection with high flash point will be bound to lead to the formation of abnormal carbon deposits,



Courtesy of Westinghouse Air Brake Co.

Fig. 6.—Phantom view of a two-cylinder horizontal, motor driven compressor showing details of construction. All wearing parts are splash lubricated.

especially if the oil has not been subjected to the most careful refinement, filtered, or is a product of an unsuitable grade of crude oil.

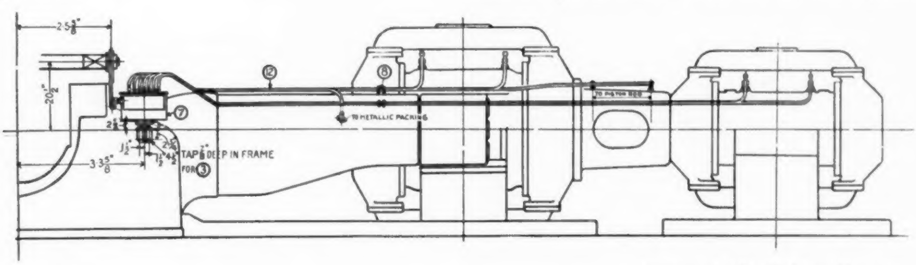
While an air compressor oil should have a viscosity high enough to sustain the weight of the moving parts, and form a proper seal between the piston rings and the cylinder walls, it should never be so high as to cause reduction in atomization or involve excessive internal friction. Moreover, if too heavy an oil is used, it will collect any dust that may be present in the air and will tend to bake on the hot surfaces and form carbon deposits. This is especially likely to happen when more oil has been used than just sufficient to lubricate the wearing surfaces.

Flash and Fire Points

While there has been considerable controversy among engineers in the past regarding the relative merits of high and low flash point oils for air compressor service, research has practically settled this point of argument decisively in favor of the latter. It has been proven that high flash and fire points have been decidedly over-emphasized in their relative importance as

qualifications for air compressor lubricants. In fact, observation of the conditions under which explosions will tend to occur has further developed that high flash points will practically always lead to the greater formation of deposits which are known to be dangerous. Therefore the air compressor operator should make sure at all times, that he is getting a proper and sufficiently low flash point compressor oil; in other words, he should specify that the flash be below 400 degrees F.

High flash oils also have high distillation end points. The cylinder walls are cooled by water-jacketing and hence the temperature of the oil layer next to the wall is practically little above that of the wall itself. The oil layer exposed to the heated air, however, becomes much hotter than the rest of the oil body and a portion of it will be vaporized. As oils, especially blended lubricants, are composite mixtures, different portions will be distilled or vaporized at different temperatures. Certain of the lighter products may pass off even at temperatures below the flash point, leaving the heavy ends dissolved in the oil next to the wall. The final result, in the case of high flash oils, is therefore oxidation and the building up of a gummy mass which has such a low vapor pressure and high distillation point, that it is not taken up by the air as fast as is necessary. Oils which have a lower flash point distill without forming this gummy mass and do not decompose as readily as higher flash oils.



Courtesy of Allis-Chalmers Mfg. Co.

Fig. 7.—Line sketch of oiling connections on a horizontal compressor. At "7" is shown a mechanical force feed oil pump. Oil piping therefrom is indicated by heavy black lines.

In any installation, where such deposits are present and are rendered incandescent for any reason whatsoever, an explosion may occur irrespective of the flash or fire points of the lubricating oil. Otherwise the oil would have to be submitted to a temperature much higher than its laboratory flash point before combustion could take place. As this temperature would be in the neighborhood of 1100 degrees F., the operator can readily appreciate that any worries he may have concerning the possibility of certain compressor oils being the more explosive, simply because their flash point is below the temperature of the discharged air, are unwarranted; provided that *carbon deposits* and *leaky air (discharge) valves* are guarded against.

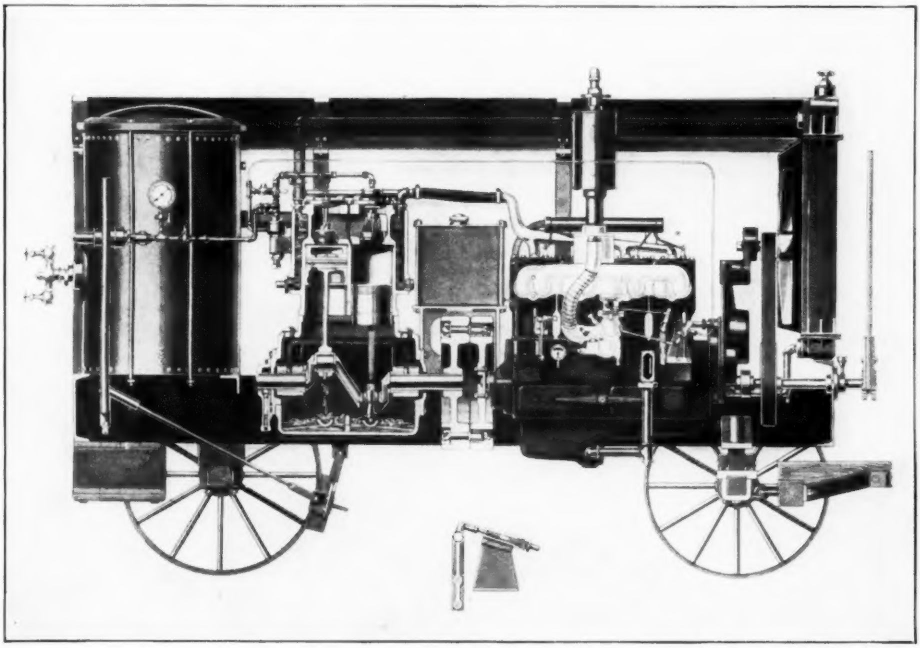
It is interesting to note in this connection that a recent report on air compressor explosions states that in every case investigated the flash points of the lubricating oils ranged from 500 degrees to 600 degrees F.

In the Diesel engine, for example, certain of the most successful lubricants developed have flash points below 400 degrees F., yet, the temperatures involved in such a machine may run as high as 1000 degrees F., proving that the use of an extremely high flash point oil is not necessary.

Carbon Deposits

Deposits of carbon plus dirt on the valves or in the discharge lines of an air compressor are to a certain extent, caused by decomposition of the oil. It is an accepted fact that mineral lubricating oils, regardless of their base or nature, will decompose to volatile products and carbon when subjected to hot air under pressure. The extent of this decomposition of course depends on the length of time the oil is exposed to such heat. Naturally, also it will follow that the oil which remains in the compressor cylinder or on the discharge valves the longest, will form the greatest amount of carbon. On the other hand, analysis of numerous so-called carbon deposits has proven them to consist more of dirt than of carbon, the whole

being held together by gummy matter from decomposed oil. For this reason an oil having a wide range of distillation, high end point, or too great a viscosity is objectionable, inasmuch as, instead of vaporizing cleanly, it breaks down as has been mentioned above, becoming sticky and collecting dirt brought in by the air. The slower the breaking down process, or the greater the volume of oil involved, the more carbon will ultimately be formed.



Courtesy of Chicago Pneumatic Tool Co.

Fig. 8.—Sectional view of a portable vertical air compressor showing details of splash lubricated compressor parts.

Carbon may be formed in cylinders in a hard mass or it may be produced in the shape of dust and pass out with the air. In the latter case, it will often collect in pockets, elbows or on sharp edges and become mixed with dirt taken in by the air as well as with oil which has been vaporized in the cylinder, and later condensed at these points. If deposited in the cylinder, carbon, being a poor conductor, may become heated considerably above the temperature of the cylinder walls; but whether it can become sufficiently heated to ignite or not is still a matter of dispute. However that may be, hard carbon is always a nuisance, and many times it accumulates on the valves and valve seats and is packed firmly into the ends of the cylinders, causing the valves to leak and frequently resulting in the cutting of the valves and scoring of the cylinders. Cases have been found where carbon deposits have collected in the valve passages and bends of piping to such an extent as to restrict the opening through which the compressed air had to pass. When once started, such formations continue to build up, so narrowing the passage that pressures may be produced capable of eventually causing an explosion.

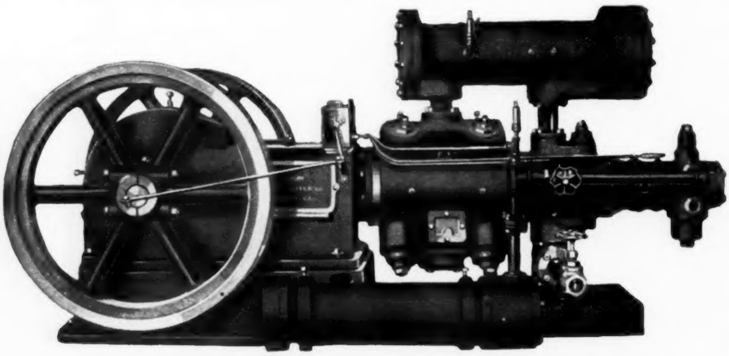
Courtesy of Brunner Mfg. Company

Fig. 9.—A type of motor driven air compressor adapted to automotive and small machine shop service.

Pale filtered oils, properly refined, are very free from both direct carbonization and the collection of carbonaceous matter. Furthermore, any such direct carbon that may be formed through excessive use, is of a light, fluffy nature. Carbon deposits formed from improperly refined or unsuitable oils, on the other hand, are often of a hard flinty nature. Any oil however, will accumulate dust if the air is dirty.

The Use of Fixed Oil Compounds or Blended Oils

Whether or not the use of fixed oils of animal or vegetable nature such as rapeseed oil, etc.,



Courtesy of Bury Compressor Co.

Fig. 10.—A tandem, straight line, three-stage power driven air compressor built to develop higher pressures, and equipped for flood lubrication.

in compound with mineral products, is advantageous for air cylinder lubrication is a subject of frequent discussion today. Where moisture is present in the air to a sufficient extent to cause precipitation in the piping or receivers, or if it is impossible to completely dry the air prior to its entry into the compressor (especially where higher pressures are involved), certain authorities deem it advisable to add a small amount of compound to the mineral compressor oil, or use a specially prepared product, instead of increasing the rate of oil feed, in order to eliminate the possibility of dry pistons and cylinders with subsequent loss of compression and rusting when the machine is shut down. This is especially applicable to some types of vertical and Diesel engine compressors. The ill-effects of possibly a moderate amount of increased carbonization are overlooked by such operators, if by compounding their lubricating oils, they can be assured of relatively satisfactory lubrication.

Others regard the use of fixed oil compounds as a detriment due to the fact that they are claimed to decompose relatively slowly, especially if the mineral constituent is a blended or mixed base product. Fixed oils in fact, are not subject to distillation under average conditions; instead, when subjected to higher temperatures they will tend to break up or decompose, developing a considerable amount of tarry or gummy residue together with solid carbon.

Methods of Air Cylinder Lubrication

Granted that the oil to be used for air cylinder lubrication satisfies the requirements discussed heretofore, it is safe to state that the possibility of future difficulties due to carbon formation will depend upon the method of feeding the oil and the quantity supplied. In fact, many authorities feel that this entire matter of efficient air compressor cylinder lubrication hinges upon the amount of oil used. Any excess supplied over that actually required will involve one of two alternatives:

a. That the oil will either be consumed by vaporization and breaking down in the compressor with the formation of a certain amount of direct carbon, or

b. That it will be carried over with the air to subsequently collect in the intercooler or in pockets elsewhere in the system.

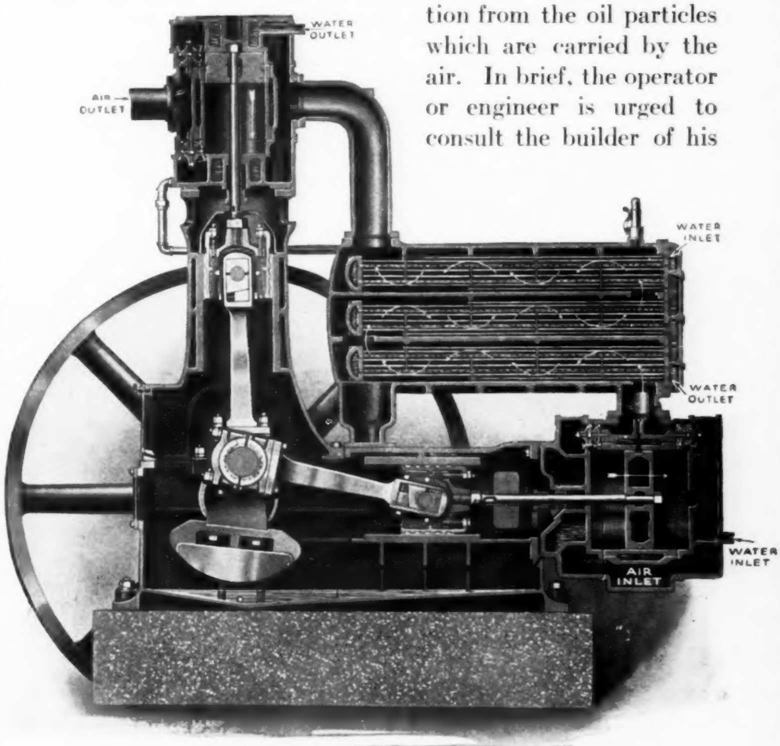
As is the case in steam cylinder lubrication, the oil will function best where it is completely atomized prior to being delivered to the cylinder. To effect such atomization in small and medium-sized compressors, the oil is often introduced at or above the point of air intake, the inrush of air carrying the atomized particles or spray of oil to all parts requiring lubrication. On account of the lesser amount of oil involved, and the fact that a filtered oil is more readily atomized, the lubricator can in such cases, be located fairly near the intake as atomization is effected in a shorter distance of travel than where steam cylinders are involved.

Air, however, does not carry oil particles as

readily as does steam. Horizontal compressors, therefore, may not receive sufficient oil at the uppermost parts of the piston and cylinder to insure satisfactory lubrication unless, of course, the oil feed is increased above the usual theoretical requirements. This is inadvisable, since the bottom parts of the cylinder, being probably over lubricated, will lead to the collections of oil in pockets, with ultimate carbonization or even the possibility of explosion. In such cases, the better procedure is to feed the oil directly to the sliding surfaces by means of sight feed drip oilers or force feed lubricators. This, in fact, is customary practice on all large installations. Oil introduced in this manner is distributed to the cylinder walls by the wiping action of the piston.

Automatic lubrication by means of force feed lubricators whereby the flow of oil to each part of the cylinder can be regulated, is perhaps the most efficient and economical method so far employed. By its use, the possibility of overfeeding oil by any particular lubricator is reduced, oil flow stops and starts with the compressor, and the requisite lubricating and sealing film is attained. Force feed lubricators are not affected by variations in air pressure, and they will feed the oil continually in accordance with their adjustments and the speed of the compressor.

Of course, different types of compressors will naturally involve certain variations in their lubrication; in fact, they may even require radical departure from what are normally classed as standard methods of lubrication. In general, however, the sight feed, hand regulated, or automatic (force feed) lubricator must be used; the application, etc., being planned according to the recommendations of the compressor builder, based on the design of the machine, its size, capacity, and the character of the valves employed. Certain of the latter, such as flap and plate valves ordinarily require no lubrication. Others, such as grid, Corliss and poppet valves require either direct application of oil, or will receive the requisite lubrication from the oil particles which are carried by the air. In brief, the operator or engineer is urged to consult the builder of his machine either when planning on lubricator installations, etc., or when he feels his lubrication is faulty. As often as not, the oil is perfectly adapted to his machine requirements, the methods of application being at fault.



Courtesy of Sullivan Machinery Co.

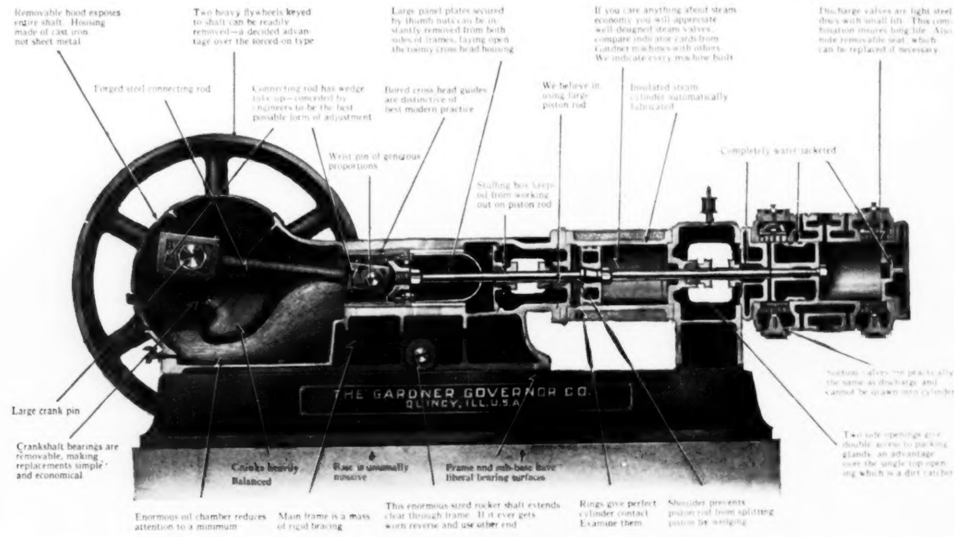
Fig. 11.—An angle-compound compressor shown in detail to illustrate arrangement of parts. Lubrication is practically automatic consisting of a self-contained gravity system for the main working parts and a force feed system for the cylinders.

Amount of Oil Required

To attempt to establish any hard and fast rule in regard to the theoretically proper amounts of oil that should be supplied to an air compressor cylinder is never advisable. Too many variables, such as the size of the compressor, its speed, and the condition of the piston and piston walls are involved. Essentially we must guard against over-lubrication, inasmuch as more trouble will be caused by the use of too much rather than too little oil.

It must be remembered that the oil will prob-

ably remain in an air compressor cylinder considerably longer than in the cylinders of either a steam or internal combustion engine, owing to the fact that there is little or no washing action or dilution of the oil film involved. As a consequence, very much less oil will be required per unit of cylinder surface over the same time interval. It is a safe rule to use just enough oil to prevent frictional wear and to permit easy and free operation of all parts; more than this will lead to trouble. If the lubricant is unsuitable, an excessive amount will be required to keep the pistons from groaning in the cylinders; in addition, the result of using an excessive amount of oil will be carbonization in the air passages, and particularly on the discharge valves. Sticking of these valves, with the passage of hot compressed air back into the compressor cylinder, is a sure sign of too much oil. The discharge valves should therefore be examined regularly, and the aftercooler, receiver, or discharge pipes periodically blown out. This will effectively remove any oil, water or sediment, which may have accumulated. If upon removal, the discharge valves have a greasy appearance, enough oil is being fed to the cylinders; on the other hand, if the parts appear very oily or little pools of oil are found in compressor pockets, or in any of the air lines, oil is being fed in excess of that required. There is a general rule to the effect that air compressors are sufficiently lubricated if one or two drops of the proper grade of oil are used for each 500 or 600 square feet of cylinder surface swept by the piston per minute. This rule, on the other hand, must be governed by the condition of the cylinders and the temperature and degree of compression.

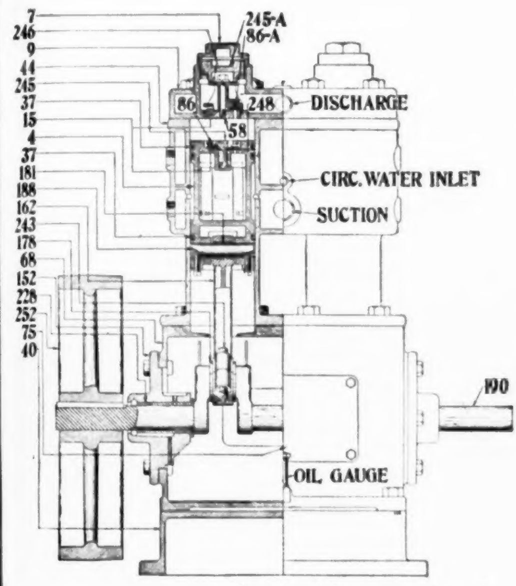


Courtesy of The Gardner Governor Co.

Fig. 12.—Interior view of a steam driven compressor showing details of construction, as brought out by the manufacturers.

The number of drops of oil which can be secured from a certain amount of any grade of oil varies with the viscosity, temperature, service conditions involved and the diameter and shape of the lubricator orifice. Therefore, the number of drops secured per minute from an oil having a Saybolt viscosity of 200 seconds at 100 degrees F. would differ from the number secured from an oil of 300 seconds viscosity. Also the type or design of lubricator, i.e., whether mechanical, force feed or hydrostatic, would affect the number of drops obtained. As a result, it is not considered good practice to make a recommendation of the number of drops per minute that should be used in air cylinders of various sizes on account of the great variation in operating conditions that will be met with. In fact, two compressors of the same design, same size, and built by the same manufacturer, may be operating in a room under identical conditions, yet, it will be practically impossible to secure the same fit of pis-

ton rings and valves and the same polished cylinder surfaces. Experience has shown that two such compressors may require a surprisingly different amount of oil for air cylinder lubrication.



Courtesy of Union Steam Pump Co.

Fig. 13.—A vertical high speed compressor designed for splash lubrication of all wearing parts. Numbers refer to manufacturers spare parts list.

In addition, the varying temperatures of the room will affect the feed of the lubricator, and while the operator may adjust the latter to give the same number of drops at different temperatures, with certain types of lubricators the difference in the size of the drops, and hence in the amount of oil fed to the cylinder will be quite appreciable.

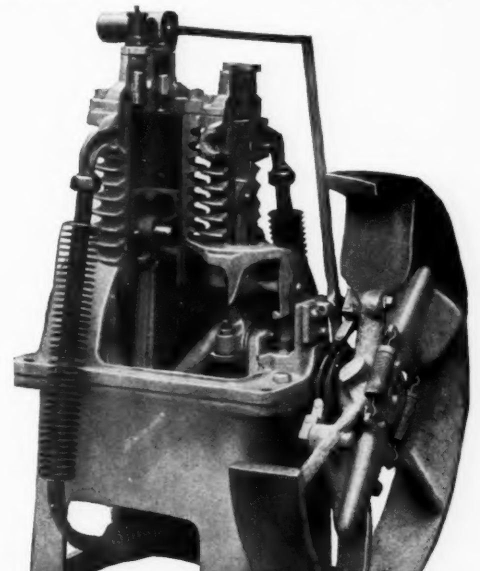
Air Compressor Explosions

This matter of explosions is of the utmost importance to all who have to deal with air compressor operation and lubrication. Extensive investigations have been made regarding their origin by scientists and technical societies throughout the world. The consensus at present is that many of such so-called explosions occur due to accumulations of carbonaceous matter becoming heated to the point of combustion when abnormally high temperatures are involved due to leaky valves, either causing the metal to burn through and blow out, or bringing about the ignition of gaseous (oil and air) vapors which may have resulted from oil collections in pockets, etc. Localized vaporous accumulations of this nature will practically always become sufficiently condensed in time to form a "critical" or combustible mixture of air and oil vapor, requiring only intense heat or a spark from incandescent carbon to bring about an explosion.

Results of experiments carried out by the Bureau of Mines* are interesting in this regard, as they show the limits of inflammability of mixtures of air with certain gases, viz:

TABLE No. 2

GAS	*Gas Mixture in Air, Per Cent.*
Gasoline Vapor	1.5 to 6
Ethane	2.5 to 5
Methane	5.5 to 14.5
Natural Gas	5 to 12
Acetylene	3 to 73
Artificial Illuminating Gas	7 to 21
Hydrogen	10 to 66
Carbon Monoxide	15 to 73
Blast-furnace Gas	36 to 65



Courtesy of Curtis Pneumatic Machinery Co.

Fig. 14.—A two-stage vertical air cooled compressor. In this machine a fan flywheel helps to circulate air around cylinder radiators and intercooler. Splash lubrication is customary.

Two distinct factors therefore, require consideration, i.e.:

1. The extent to which carbon deposits or accumulations of dust, dirt and oil, etc., are involved, and

*Technical paper 150 G. A. Burrell and A. W. Gauger. Bureau of Mines, U. S. A., 1917.

2. The generation of excess heat, due either to air leaks in the discharge or final stage of compression, especially at the time of "unloading", or increased velocity of flow through the lines.

Carbon deposits or "carbonaceous" matter in general, does not strictly denote pure carbon, or in other words, carbonized oil. In fact, the proportion of fixed carbon to volatile matter and ash in numerous samples of such deposits analyzed, is relatively low. An average of ten analyses is given in one report* as follows:

Fixed Carbon	22.6%
Volatile Matter	55.7%
Ash (Calcined)	21.7%

In some cases these samples were soft, in others, dry and hard. Silica, iron, copper and zinc were all more or less present, proving that a considerable portion of any such deposits can therefore be regarded as consisting of substances which are either drawn in by the original charge of air, or abraded from the metallic parts of the system. In other words, the lubricating oil as a source of carbon is but partially responsible.

The above analyses indicate that such deposits are not only capable gas reservoirs, but that they are of such a nature as to be liable to spontaneous combustion, especially in the presence of metals which, in a finely divided state will accelerate the process of oxidation, since these metal particles are maintained in an unoxidized condition by means of a protecting film of oil.

Another point of interest is the fact that practically all air compressor failures occur at some point more or less distant from the compressor itself, such as in the aftercoolers, receivers or delivery piping. The air at these points would certainly be cooler normally than when it leaves the compressor cylinder. Due to congestion by carbon deposits, however, resulting from perhaps dirty air or use of excess oil, the passage of air through such constricted areas will often result in overheating on account of marked increase in velocity. Explosions have also occurred due to the receivers and discharge piping being entirely inadequate in size to handle the volume of air at normal velocity, when additional compressors have been installed without any corresponding increase in the size of the lines.

To sum up, Mr. Vaughan states that .... "Firing is not difficult to account for" .... because, while .... "current lubricating oil cannot provide sufficient gas for firing or explosion, large masses of deposits can do so. Even at *Full Load* where the flow of air is restricted by accumulation of thick deposits in the intercooler, it is possible that overheating and subsequent ignition may occur"....

Conclusion

We are therefore faced primarily with the problem of eliminating, as far as possible, the likelihood of air compressor explosions. This becomes a relatively simple matter if we remember that efficient operation is brought about by:

1. *Using Clean Cold Air*—to keep temperatures down and prevent dust and dirt from entering the system. If this cannot be obtained naturally, use an air cleaner or filter.

2. *The Use of Cold Water*—to insure as low a cylinder temperature as possible.

3. *The Use of Soft Water*—to prevent scaling of cooling water jackets.

4. *Periodic Inspection of Valves, etc.*—to note extent of lubrication, and whether carbon formation is occurring.

5. *Cleaning of Air Cylinders About Once a Week*—using a soft soap wash (feeding same into system instead of lubricating oil for several hours) in order to remove carbon formations. Air lines to receiver should be thoroughly blown out after each wash.

6. *Periodic Inspection of Cooling Water Jackets*—to note extent of scale formation. Also cleaning if necessary.

7. *Installing an Aftercooler*—to cool and condense oil so that it can be properly drained from the system.

8. *Installing a Receiver*—to equalize air pressures.

9. *USING GOOD OIL*, and just enough of it to lubricate the air cylinders properly. Judge this by the condition of your valves and cylinder walls.

*"Explosions in Air Compressors" by J. A. Vaughan from "The Journal of the South African Institution of Engineers."

Certain other conclusions have been abstracted elsewhere from Mr. Vaughan's paper.

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